ASSESSMENT OF BLAST EFFECT OPEN PIT „RANCI" OF SHOCK WAVES ON CONSTRUCTED FACILITIES AND ENVIRONMENT

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ABSTRACT

The blast effect problem of shock waves is growing in the area surrounding blasting activities. In addition to damage shock waves may cause on buildings and mining site facilities, they also impact badly human force there, namely the environment. Lately considerable research in the world has been dedicated to the examination and numeric modelling of this phenomenon. Specific standards have been established defining the blast effect margin level of shock waves on facilities and human force there. Numerous numerical and empirical models have been developed to predict and monitor them. In Serbia, there are no standards for the assessment of blast effect of shock waves. This paper deals with the assessment of blast effect of an open pit mine and specific conclusions that have been drawn.

KEY WORDS

Blasting, Shock wave, Measurement, Assessment, Margin level, Standard.

1. INTRODUCTION

While carrying out mass blasts or blasting in urban environments where there are at the same time activated explosive amounts from several to several thousand kilograms, adverse effects of blasting can occur. At a particular moment those adverse effects can be a problem for safe and secure blasting operations, especially if people, varied constructed facilities, both on the surface and underground, are in the vicinity. Adverse effects occurring while blasting are shock waves, seismic effects, fumes, flyrock, etc. [1]

Needs for the growing production of mineral raw materials have conditioned the use of a large quantity of explosives, which leads to the improvement of technical-economical indicators and, on the other hand, to the increase of adverse effects accompanying blasting activities. Growing presence of blasting techniques in mining results from the fact that single blasting can replace the work of a large number of workers and machines for a several month period.[1]

By carrying out blasting activities potential explosive energy is transferred into mechanical work. That energy destroys and crushes a rock mass in the vicinity of a blast site further causing fractures and permanent deformations in a rock mass, and, even further, is transferred into elastic deformations. Seismic waves spreading through a rock mass cause the oscillation of soil and facilities, impact on the environment, etc.[1]

2. EFFECTS OF BLASTING ON CONSTRUCTED FACILITIES

The intensity assessment of shock waves induced by blast work breaking a rock mass and its impact on construction facilities and an environment will be carried out on the basis of the following criteria: [3]

A. Effects of blasting on constructed and mine facilities

a) Criterion according to the Institute of Physics of the Earth, Russian Academy of Sciences (IPERAS) scale

b) Criterion according to the standard DIN- 4150 and

B. Effects of blasting on environment

a) Criterion according to the standard DIN- 4150. [3]

A. Effects of blasting on constructed and mine facilities

*** The criterion according to the IPERAS scale.** One of the most commonly used criteria with us for the assessment of shock wave intensity induced by blasting has been established by the Institute of Physics of the Earth, Russian Academy of Sciences. The Russian scale (Table 1.) is of a descriptive type related to the ocsillation velocity of soil particles and the degree of seismic intensity and is given in the form of 12 seismic degrees. [3]

Table 1. IPERAS scale

Oscillation Velocity v [mm/s]	Level of seismic intensity	DESCRIPTION OF ACTIONS
To 2.0	I	Action is revealed only by instruments
2.0 – 4.0	II	Action is felt only in some cases when there is a complete silence
4.0 – 8.0	III	Action is felt by very few people or only those who are expecting it
8.0 – 15.0	IV	Action is felt by many people, the clink of the windowpane is heard
15.0 – 30.0	V	Plaster fall, damage on buildings in poor condition
15.0 – 30.0	V	Plaster fall, damage on buildings in poor condition
30.0 – 60.0	VI	Air cracks in plaster, damage, damage to buildings that already have developed deformations
60.0 – 120.0	VII	Damage to buildings in good condition, cracks in plaster, parts of the plaster fall down, air cracks in walls, cracks in tile stoves, chimney wrecking
120.0 – 40.0	VIII	Considerable deformations on buildings, cracks in bearing structure and walls, bigger cracks in partition walls, wrecking of factory chimneys, fall of the ceiling
240.0 – 480.0	IX	Wrecking of buildings, bigger cracks in walls, exfoliation of walls, collapse of some parts of the walls
Bigger than 480.0	X - XII	Bigger destruction, collapse of complete structures etc.

Deformations on the facilities, as it can be seen in Table 1., occur if oscillation velocity owing to blasting exceeds the fourth degree of the seismic scale. The state of the facilities, soil charscteristics, as well as the number and kinds of blasting activities should be taken into account for the assessment of blasting seismic effects on buildings and other constructed facilities. [3]

* **Criterion according to standard DIN-4150** – In the Federal Republicof Germany, maximal tolerable limits for the values of soil oscillation velocity are regulated in dependence on the significance and the state of facilities for the frequency span from 5 to 100 Hz. Tolerable limits for the values of the soil oscillation velocity according to DIN- 4150 are presented in Table 2. [3]

Table 2. Standard DIN-4150

<table>
<tr><td rowspan="4">Row</td><td rowspan="4">Type of the structure</td><td colspan="4">Approximate values of vibration velocity (v) mm/s</td></tr>
<tr><td colspan="3">Foundation</td><td>Top floor ceilings</td></tr>
<tr><td colspan="3">Frequency, HZ</td><td rowspan="2">All frequencies</td></tr>
<tr><td>< 10</td><td>10-50</td><td>50-100</td></tr>
<tr><td>1</td><td>Structures used for craftsmanship, industrial and similar structural structures</td><td>20</td><td>20–40</td><td>40–50</td><td>40</td></tr>
<tr><td>2</td><td>Dwelling buildings and structures similar in construction or function.</td><td>5</td><td>5–15</td><td>15–20</td><td>15</td></tr>
<tr><td>3</td><td>Structures that because of their particular sensitivity to vibrations do not fall into groups 1 and 2 and are essential for conservation (for inst. as cultural-historical monuments)</td><td>3</td><td>3–8</td><td>8–10</td><td>8</td></tr>
</table>

B. Effects of blasting on environment

* **Effects on people in constructed facilities (buildings) according to DIN criteria –** data on vibration assessment in the frequency span from 1 to 80 Hz are given by this standard. It is possible to evaluate any periodical and a-periodical oscillations by the assessment procedure. In the standard, there are stated requirements and approximate stress values of people in flats and rooms used for similar purposes. [3]

Jeopardizing of people by shock waves depends on the following factors: shock wave intensity (strength), frequency, duration of shock waves, frequent recurrence and the period of a day when they occur, the sort and way of work of a shock wave source, individual characteristics and situational circumstances, health state (physical psychical), activity during shock wave stress, the level of becoming used to them.

The assessment procedure of vibrations is taken on the basis of unweighted signals expressed by the vibration intensity KB_F. During assessment the maximal weighted vibration intensity KB_{Fmax}, is determined and if necessary the vibration intensity during assessment KB_{FTr} which are compared with approximate values.

An unweighted vibration signal is a signal limited by the span and proportional to the vibration velocity in the operating frequency range from 1 to 80 Hz.

A frequently weighted signal of vibrations is obtained from an unweighted vibration signal by filtration. The obtained signal is weighted by the calculating procedure according to the relation:

$$\left|H_{KB}(f)\right| = \frac{1}{\sqrt{1+\left(\frac{f_0}{f}\right)^2}} \tag{1}$$

where there is: f – frequency in Hz; f_0 = 5.6 Hz (threshold frequency of high permeability filter).

On the basis of the obtained weighted signal, the KB value with time constant τ = 125 ms is calculated based on the relation:

$$KB_{\tau}(t) = \sqrt{\frac{1}{\tau}\int_{\xi=0}^{\xi=t} e^{-\frac{t-\tau}{\tau}} KB^2(\xi)\cdot d\xi} \qquad (2)$$

While determining weighted KB values, as experience shows, the aberration of 15% occurs.

The measurement of oscillation values must be carried out in the vertical direction (z) with two horizontal directions being at the right angle (x and y).

The assessment of obtained results according to DIN 4150 is carried out on the basis of two KB values:

- KB_{Fmax} - maximal weighted vibration intensity (maximal KBt value),
- KB_{FTr} - maximal effective value in time interval.

The effective value of maximal values in time intervals KB_{FTr} is determined via the relation:

$$KB_{FTm} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} KB^2{}_{FTr}} \qquad (3)$$

Both values (KB_{Fmax}, and KB_{FTr}) are determined separately for all three components in x, y (horizontal) and z (vertical) directions. The assessment is carried out on the basis of that component which is the highest.

Values for assessment should be compared with approximate values: *A_u- lower margin, A_o- upper margin and A_R- resulting value,* in Table 3. under the following conditions:

Table 3. Approximate values

Row	Workplace	D a y			Night		
		A_u	A_o	A_r	A_u	A_o	A_r
1	A workplace where, in the vicinity, there are only industrial plants and possibly flats for owners, managers and monitorial staff and workers on duty (see industrial regions Article 9 Bau NVO, (Land Use Ordinance).	0,40	6,0	0,20	0,30	0,60	0,15
2	A workplace where, in the vicinity, there are predominantly located handicraft facilities (see craft fields Article 8. Bau NVO-(Land Use Ordinance).	0,30	6,0	0,15	0,20	0,40	0,10
3	A workplace where, in the vicinity, there are neither predominantly located industrial plants nor flats (see central areas Article 6. Bau NVO, rural areas Article 5. Bau NVO- Land Use Ordinance).	0,20	5,0	0,10	0,15	0,30	0,07
4	A workplace where, in the vicinity, there are predominantly or exclusively residential areas (see pure residential areas Article 3 Bau NVO, general residential areas Article 4. Bau NVO, small settlement areas Article.2. Bau NVO).	0,15	3,0	0,07	0,10	0,20	0,05
5	A workplace work requiring special protection, for example in hospitals, spa resorts, as well as special areas denoted for that purpose.	0,10	3,0	0,05	0,10	0,15	0,05

* if KB_{Fmax} value is lower than (upper) approximate value A_o or the same, then requirements according to this standard are met.

* if KB_{Fmax} is higher than (upper) approximate value A_o then requirements according to this standard are not met.

* for momentary activities which rarely occur, the requirement according to the standard is met if KB_{Fmax} is lower than A_o.

* for more frequent activities, where KB_{Fmax} is higher than A_u but lower than A_o, another step of investigation is required in special cases, namely the determination of the vibration intensity

for the assessment of KB_{FTr}. If KB_{FTr}. is not higher than the approximate value A_r, according to the Table 3., then the requirements according to the standard are also met.

* the criterion A_r serves for the assessment of highly variable or only momentarily acting variations whose value KB_{Fmax} is higher than A_u, but lower than A_o.

3. CONDITIONS OF BLASTING AND MEASUREMENT CONDUCTING

The deposit location - The Ranci limestone deposit is situated on the farthest east slopes of the Suvobor mountain massif. The deposit is situated north–east of the town of Gornji Milanovac and south of the town of Ljig. The study area belongs administratively to the municipality of Gornji Milanovac and the land registry of the village of Boljkovci. [2]

Geological setting - The deposit belongs to the group of exogenetic deposits. According to the genetic classification, the deposit belongs to a sedimentary type. The form of the ore body according to inner contours, defined by the research work is generally parallelepiped where the parallelepiped length along the NE-SW strike is for about 210.0 m greater than the width along the NW-SE strike and about 22 times greater than the average thickness of the productive deposit series.

On the basis of laboratory analyses of dolomite from the open pit Ranci- in the vicinity of the town of Ljig, the following values of the most essential physico-mechanical properties have been determined:

* Comprehensive strength (mean values)	
- in dry state - in water saturated state	156 MPa 135 MPa
* Volume mass with interstices	2.82 g/cm^3
* Volume mass without interstices	2.85 g/cm^3
* water suction	0.217 %
* Velocity of longitudinal waves	5633,2
* Velocity of transversal waves	2659,2

The measuring of seismic effects, namely the oscillation velocity of soil particles (v) induced by blasting was carried out by a measuring device of Vibralok type, a product of the Swedish Company ABEM. Basic characteristics of the seismograph Vibraloc are the following: [3]

- Manufacturer	*ABEM, Sweden*
- Measurement possibilities	*velocity, acceleration, motion and air impacts*
- Number of components	*lateral, vertical, longitudinal*
- Frequency range	*2 - 250 Hz*
- Sampling	*1000; 2000 or 4000 Hz*
- Trigger levels	*0.1 – 200 mm/s*
- Trigger levels of the canal A (air)	*2 – 150 Pa*
- Recording length	*1 – 100 s or automatic length*
- Site location possibilities	*flat floors, plates, foundations, soil etc.*
- Data transfer and analysis	*UVSZ software; UVSZA software*

Measurement points were located at the following locations:

- Measurement point MM-1	constructed facility – a house
- Measurement point MM-2	constructed facility – a house
- Measurement point MM-3	constructed facility – a house
- Measurement point MM-4	constructed facility – a house

3.1. Data on conducted blasting and measuring No. I

♣ **Data on blasting: -** The following means were used for this blasting: [1]

- Overall number of boreholes N_{uk} = 11
- Overall depth of boreholes L_{uk} = 135,0 m
- Amount of explosive – Riogel 60/1785 Q_1 = 98,17 kg
- Amount of explosive – Anfo-J Q_2 = 186,0 kg
- Overall amount of explosive Q_{uk} = 284,17 kg
- Max. amount of explosive per one interval Q_i = 25,92 kg
- Length of intermediary stemming L_{ms} = 1,0 – 1,2 m
- Length of stemming Ls = 3,6 – 4,2 m
- Rudnel detonators, 25/4500 ms N_u = 22 piece
- Amount of slow-burning fuse L_{sf} = 1,0 m
- Delay action cap, DK-8 N_{DK} = 1 piece

♣ **Instrumental observations** –The recording of seismic waves was carried out with four to five instruments. In Table 4. there are presented results of measuring for each measurement point. [1]

Table 4. Instrumental observations

Measu ring poi. M.P.	Dist. from blasting field to measuring point, *m*	Max. quantity per one inter. *kg.*	Overall quantity of exp. in kg.	Max. oscillation velocity per comp. *mm/s*			Max. oscilla. velocity per comp. v_r, *mm/s*	Real result. max. oscilla. velocity v_{st}, *mm/s*	Evaluation of measurement results *Hz*		
				V_V	V_T	V_L			*V*	*T*	*L*
MM-1	321,0	25,92	284,17	2,013	2,759	1,839	***3,879***	***3,120***	30,2	22,3	31,2
MM-2	282,0	25,92	284,17	2,999	2,971	2,227	***4,773***	***3,630***	48,8	52,8	55,8
MM-3	200,0	25,92	284,17	4,411	7,192	2,697	***8,857***	***7,390***	37,9	37,5	40,0
MM-4	342,0	25,92	284,17	1,528	1,485	1,348	***2,521***	***1,990***	44,1	48,1	40,0

3.2. Data on conducted blasting and measuring No. II

♣ **Data on blasting: -** The following means were used for this blasting: [1]

- Overall number of boreholes N_{uk} = 24
- Overall depth of boreholes L_{uk} = 292,0 m
- Amount of explosive – Riogel 60/1785 Q_1 = 208,84 kg
- Amount of explosive – Anfo-J Q_2 = 384,00 kg
- Overall amount of explosive Q_{uk} = 592,84 kg
- Max. amount of explosive per one interval Q_i = 26,71 kg
- Length of intermediary stemming L_{ms} = 1,0 – 1,2 m
- Length of stemming Ls = 3,5 – 4,5 m
- Rudnel detonators, 17/4500 ms N_u = 48 piece
- Amount of slow-burning fuse L_{sf} = 1,0 m
- Delay action cap, DK-8 N_{DK} = 1 piece

♣ **Instrumental observations** –The recording of seismic waves was carried out with four to five instruments. In Table 5. there are presented results of measuring for each measurement point. [1]

Table 5. Instrumental observations

Measu ring poi. M.P.	Dist. from blastin field to measuring point, *m*	Max. quantity per one inter. *kg.*	Overall quantity of exp. in kg.	Max. oscilation velocity per comp. *mm/s*			Max. oscila. velocity per comp. v_{r}, *mm/s*	Real result. max. oscilla. velocity v_{st}, *mm/s*	Evaluation of measurement results *Hz*		
				V_V	V_T	V_L			*V*	*T*	*L*
MM-1	330,0	26,71	592,84	1,425	1,501	1,570	***2,597***	***1,920***	27,5	19,0	30,2
MM-2	290,0	26,71	592,84	1,250	1,131	1,035	***1,978***	***1,550***	50,6	50,2	57,7
MM-3	210,0	26,71	592,84	2,602	6,177	2,233	***7,065***	***6,600***	37,4	35,9	27,7
MM-4	331,0	26,71	592,84	1,638	1,395	0,840	***2,309***	***1,950***	48,5	37,5	47,7

3.3. Data on conducted blasting and measuring No. III

♣ **Data on blasting: -** The following means were used for this blasting: [1]

- Overall number of boreholes N_{uk} = 28
- Overall depth of boreholes L_{uk} = 285,0 m
- Amount of explosive – Riogel 60/1785 Q_1 = 282,03 kg
- Amount of explosive – Anfo-J Q_2 = 560,00 kg
- Overall amount of explosive Q_{uk} = 842,03 kg
- Max. amount of explosive per one interval Q_i = 30,71 kg
- Length of intermediary stemming L_{ms} = 1,0 – 1,2 m
- Length of stemming Ls = 3,5 – 4,5 m
- Rudnel detonators, 25/4500 ms N_u = 56 piece
- Amount of slow-burning fuse L_{sf} = 1,0 m
- Delay action cap, DK-8 N_{DK} = 1 piece

♣ **Instrumental observations** –The recording of seismic waves was carried out with four to five instruments. In Table 6. there are presented results of measuring for each measurement point.

Table 6. Instrumental observations [1]

Measu ring poi. M.P.	Dist. from blastin field to measuring point, *m*	Max. quantity per one inter. *kg.*	Overall quantity of exp. in kg.	Max. oscilation velocity per comp. *mm/s*			Max. oscila. velocity per comp. v_{r}, *mm/s*	Real result. max. oscilla. velocity v_{st}, *mm/s*	Evaluation of measurement results *Hz*		
				V_V	V_T	V_L			*V*	*T*	*L*
MM-1	346,0	30,71	842,03	1,741	2,384	1,727	***3,420***	***2,530***	23,9	18,7	39,1
MM-2	307,0	30,71	842,03	1,908	1,286	1,372	***2,679***	***2,240***	17,4	17,7	21,9
MM-3	225,0	30,71	842,03	3,948	5,559	2,918	***7,416***	***6,140***	19,4	34,9	20,9
MM-4	320,0	30,71	842,03	1,233	1,522	1,009	**2,203**	***1,870***	40,0	41,0	37,0

3.4. Data on conducted blasting and measuring No. IV

♣ **Data on blasting: -** The following means were used for this blasting: [1]

- Overall number of boreholes N_{uk} = 36
- Overall depth of boreholes L_{uk} = 420,0 m
- Amount of explosive – Riogel 60/1785 Q_1 = 374,85 kg
- Amount of explosive – Anfo-J Q_2 = 720,00 kg
- Overall amount of explosive Q_{uk} = 1.094,85 kg
- Max. amount of explosive per one interval Q_i = 32,49 kg

- Length of intermediary stemming L_{ms} = 1,0 – 1,2 m
- Length of stemming Ls = 3,5 – 4,5 m
- Rudnel detonators, 25/4500 ms N_u = 74 piece
- Amount of slow-burning fuse L_{sf} = 1,0 m
- Delay action cap, DK-8 N_{DK} = 1 piece

♣ **Instrumental observations** –The recording of seismic waves was carried out with four to five instruments. In Table 7. there are presented results of measuring for each measurement point. [1]

Table 7. Instrumental observations

Measu ring poi. M.P.	Dist. from blastin field to measuring point, *m*	Max. quantity per one inter. *kg.*	Overall quantity of exp. in kg.	Max. oscilation velocity per comp. *mm/s*			Max. oscila. velocity per comp. v_r, *mm/s*	Real result. max. oscilla. velocity v_{st}, *mm/s*	Evaluation of measurement results *Hz*		
				V_V	V_T	V_L			*V*	*T*	*L*
MM-1	360,0	32,49	1.094,85	2,148	4,083	2,355	***5,179***	***4,210***	28,9	23,7	27,4
MM-2	320,0	32,49	1.094,85	1,727	1,596	2,340	***3,317***	***2,480***	22,2	26,1	54,2
MM-3	238,0	32,49	1.094,85	4,543	5,758	3,714	***8,221***	***5,830***	31,6	41,8	30,8
MM-4	306,0	32,49	1.094,85	1,616	3,960	1,525	**4,540**	***4,020***	39,1	37,7	33,8

3.5. Data on conducted blasting and measuring No. V

♣ **Data on blasting: -** The following means were used for this blasting: [1]

- Overall number of boreholes N_{uk} = 43
- Overall depth of boreholes L_{uk} = 480,0 m
- Amount of explosive – Riogel 60/1785 Q_1 = 399,84 kg
- Amount of explosive – Anfo-J Q_2 = 1.075,00 kg
- Overall amount of explosive Q_{uk} = 1.474,84 kg
- Max. amount of explosive per one interval Q_i = 33,92 kg
- Length of intermediary stemming L_{ms} = 1,0 – 1,2 m
- Length of stemming Ls = 3,5 – 4,5 m
- Rudnel detonators, 17/500 ms N_u = 86 piece
- Amount of slow-burning fuse L_{sf} = 1,0 m
- Delay action cap, DK-8 N_{DK} = 1 piece

♣ **Instrumental observations** –The recording of seismic waves was carried out with four to five instruments. In Table 8. there are presented results of measuring for each measurement point. [1]

Table 8. Instrumental observations

Measu ring poi. M.P.	Dist. from blastin field to measuring point, *m*	Max. quantity per one inter. *kg.*	Overall quantity of exp. in kg.	Max. oscilation velocity per comp. *mm/s*			Max. oscila. velocity per comp. v_r, *mm/s*	Real result. max. oscilla. velocity v_{st}, *mm/s*	Evaluation of measurement results *Hz*		
				V_V	V_T	V_L			*V*	*T*	*L*
MM-1	370,0	33,92	1.474,84	0,927	2,075	1,211	***2,575***	***2,080***	29,0	13,1	17,0
MM-2	332,0	33,92	1.474,84	1,091	1,354	1,430	***2,251***	***1,860***	13,6	18,3	18,7
MM-3	250,0	33,92	1.474,84	2,249	4,037	2,476	***5,242***	***4,160***	29,3	14,0	32,6
MM-4	292,0	33,92	1.474,84	3,564	6,165	3,867	**8,103**	***6,580***	50,2	41,5	42,1

3.6. Data on conducted blasting and measuring No. VI

♣ **Data on blasting: -** The following means were used for this blasting: [1]

- Overall number of boreholes	N_{uk}	= 66
- Overall depth of boreholes	L_{uk}	= 515,0 m
- Amount of explosive – Riogel 60/1785	Q_1	= 487,30 kg
- Amount of explosive – Anfo-J	Q_2	= 1.950,00 kg
- Overall amount of explosive	Q_{uk}	= 2.437,30 kg
- Max. amount of explosive per one interval	Q_i	= 38,92 kg
- Length of intermediary stemming	L_{ms}	= 1,0 – 1,2 m
- Length of stemming	Ls	= 3,0 – 4,0 m
- Rudnel detonators, 17/500 ms	N_u	= 132 piece
- Amount of slow-burning fuse	L_{sf}	= 1,0 m
- Delay action cap, DK-8	N_{DK}	= 1 piece

♣ **Instrumental observations** –The recording of seismic waves was carried out with four to five instruments. In Table 9. there are presented results of measuring for each measurement point. [1]

Table 9. Instrumental observations

Measu ring poi. M.P.	Dist. from blastin field to measuring point, *m*	Max. quantity per one inter. *kg.*	Overall quantity of exp. in kg.	Max. oscilation velocity per comp. *mm/s*			Max. oscila. velocity per comp. v_r, *mm/s*	Real result. max. oscilla. velocity v_{st}, *mm/s*	Evaluation of measurement results *Hz*		
				V_V	V_T	V_L			*V*	*T*	*L*
MM-1	384,0	38,92	2.437,30	1,402	1,920	1,346	***2,732***	***2,110***	31,6	26,6	26,5
MM-2	346,0	38,92	2.437,30	1,114	1,128	0,983	***1,865***	***1,370***	20,6	41,5	21,4
MM-3	263,0	38,92	2.437,30	1,786	3,728	1,901	***4,549***	***3,930***	30,0	11,2	16,5
MM-4	278,0	38,92	2.437,30	5,977	6,367	4,066	**9,633**	***7,270***	53,7	37,9	44,2

4. ASSESMENT OF MEASUREMENT RESULTS

The assesment of intensity of shock waves induced by blasting on breaking rock mass and its impact on surrounding facilities and environment, will be conducted on the basis of the following criteria:

A. Effects of blasting on constructed and mine facilities:

a) Criterion according to Institute of Physics of the Earth, Russian Academy of Sciences

(IPERAS) scale.

b) Criterion according to the standard DIN-4150

B. Effects of blasting on environment

a) Criterion according to the standard DIN-4150.

In order to conduct the assessment of induced shock waves by these three criteria, in Table 10., there have been given recorded values of velocity by components, resulting maximal oscillation velocity, frequency by components, as well as the KB calculated value whose values will be compared with the values presented in Tables 1. 2. and 3.

To assess the shock wave intensity the following marks were used to fill in Table 10.:

A. Effects of blasting on constructed and mine facilities

♦**The criterion according to the IPERAS scale (facilities of the third class according to Table 1. taken into account)**

A – it meets requirements within thresholds of oscillation velocity

B –it does not meet requirements, above thresholds of oscillation velocity

♦The criterion according to DIN 4150 standard (facilities of the second class according to Table 2. taken into account)

C – it meets requirements within thresholds of oscillation velocity

D – it does not meet requirements, above thresholds of oscillation velocity

B. Effects of blasting on environment according to DIN standard (Table 3.)

E – it meets requirements within threshold values

F – it does not meet requirements, above threshold values

In Figure 1 – 4. there is shown the value of wave component as well as the KB_{fm}. value.

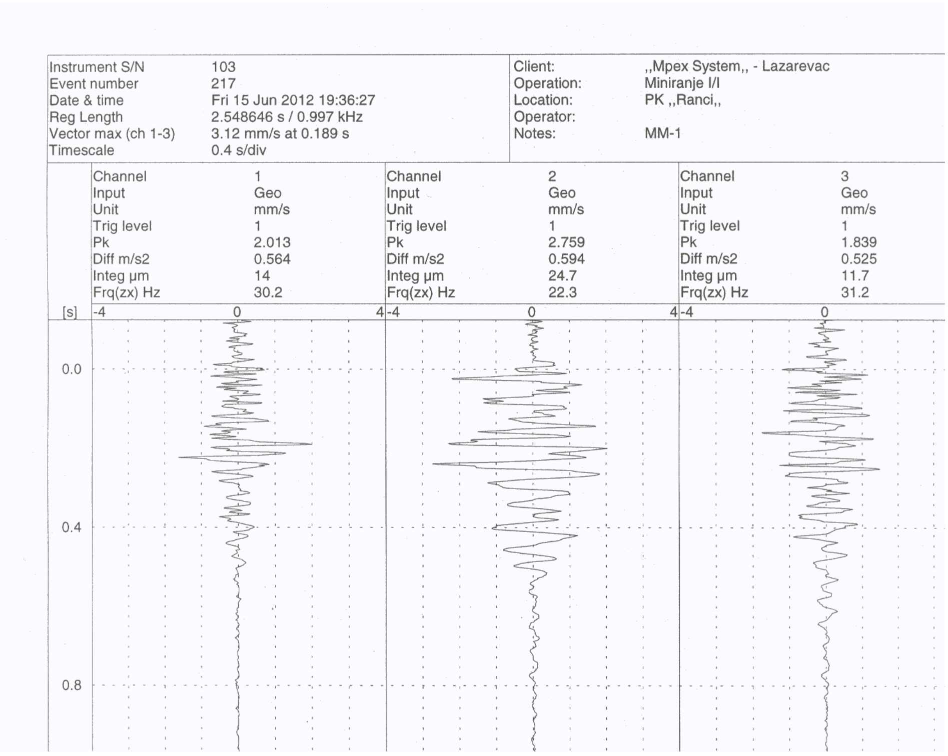

Figure 1. Velosity shot for blasting No. I, measurement point MM-1

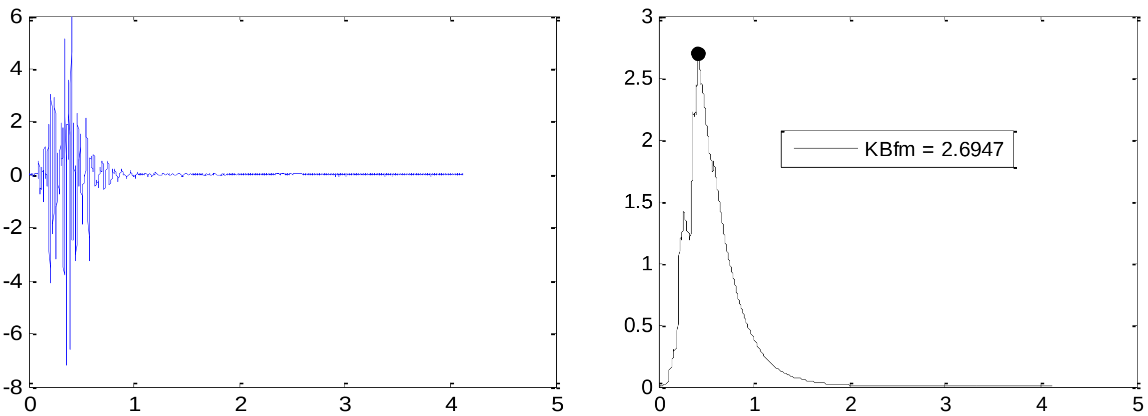

Fig. 2. Value of the vertical component V_v and KB_{fm}. Blasting number II, measuring MM-3

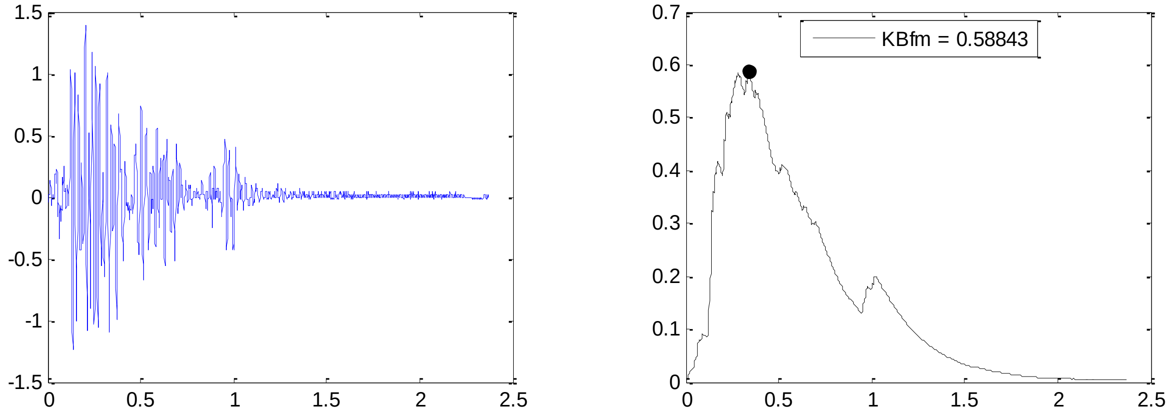

Fig.3. Value of the vertical component V_v and KB_{fm}. Blasting number III, measuring MM-4

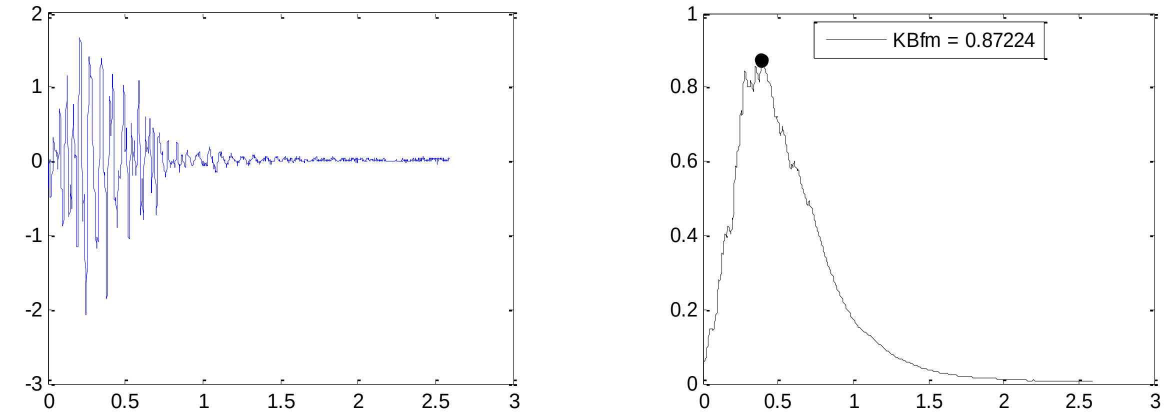

Fig. 4. Value of the vertical component V_v and KB_{fm}. Blasting number V, measuring MM-1

Table 10. Results of blasting and measuring conducted at the open pit ,,Ranci'' in the vicinity of the town of Ljiga.

Blasting No.	Measuring point M.P.	Dist. from blastin field to measuring point	Max. quantity per one inter. kg.	Overall quantity of exp. in kg.	Maximum oscilation velocity per comp. mm/s			Res. max. oscilation velocity mm/s	KB_{fm}	Frequency per components, Hz			Evaluation of measurement results		
					V_V	V_T	V_L			*V*	*T*	*L*	By IFZA	By DIN	By DIN (KB_{fm})
I	MM-1	321,0	25,92	284,17	2,013	2,759	1,839	***3,879***	*1,139*	30,2	22,3	31,2	**A**	**C**	**E**
	MM-2	282,0	25,92	284,17	2,999	2,971	2,227	***4,773***	*0,971*	48,8	52,8	55,8	**A**	**C**	**E**
	MM-3	200,0	25,92	284,17	4,411	7,192	2,697	***8,857***	*0,830*	37,9	37,5	40,0	**A**	**C**	**E**
	MM-4	342,0	25,92	284,17	1,528	1,485	1,348	***2,521***	*0,583*	44,1	48,1	40,0	**A**	**C**	**E**
II	MM-1	330,0	26,71	592,84	1,425	1,501	1,570	***2,597***	*0,499*	27,5	19,0	30,2	**A**	**C**	**E**
	MM-2	290,0	26,71	592,84	1,250	1,131	1,035	***1,978***	*0,445*	50,6	50,2	57,7	**A**	**C**	**E**
	MM-3	210,0	26,71	592,84	2,602	6,177	2,233	***7,065***	*2,694*	37,4	35,9	27,7	**A**	**C**	**E**
	MM-4	331,0	26,71	592,84	1,638	1,395	0,840	***2,309***	*0,316*	48,5	37,5	47,7	**A**	**C**	**E**
III	MM-1	346,0	30,71	842,03	1,741	2,384	1,727	***3,420***	*0,805*	23,9	18,7	39,1	**A**	**C**	**E**
	MM-2	302,0	30,71	842,03	1,908	1,286	1,372	***2,679***	*0,579*	17,4	17,7	21,9	**A**	**C**	**E**
	MM-3	225,0	30,71	842,03	3,948	5,559	2,918	***7,416***	*0,912*	19,4	34,9	20,9	**A**	**C**	**E**
	MM-4	320,0	30,71	842,03	1,233	1,522	1,009	***2,203***	*0,588*	40,0	41,0	37,0	**A**	**C**	**E**
IV	MM-1	360,0	32,49	1.094,85	2,148	4,083	2,355	***5,179***	*1,062*	28,9	23,7	27,4	**A**	**C**	**E**

	MM-2	320,0	32,49	1.094,85	1,727	1,596	2,340	***3,317***	*0,608*	22,2	26,1	54,2	**A**	**C**	**E**
	MM-3	238,0	32,49	1.094,85	4,543	5,758	3,714	***8,221***	*1,886*	31,6	41,8	30,8	**A**	**C**	**E**
	MM-4	306,0	32,49	1.094,85	1,616	3,960	1,525	***4,540***	*1,424*	39,1	37,7	33,8	**A**	**C**	**E**
V	MM-1	370,0	33,92	1.474,84	0,927	2,075	1,211	***2,575***	*0,872*	29,0	13,1	17,0	**A**	**C**	**E**
	MM-2	332,0	33,92	1.474,84	1,091	1,354	1,430	***2,251***	*0,446*	13,6	18,3	18,7	**A**	**C**	**E**
	MM-3	250,0	33,92	1.474,84	2,249	4,037	2,476	***5,242***	*1,589*	29,3	14,0	32,6	**A**	**C**	**E**
	MM-4	292,0	33,92	1.474,84	3,564	6,165	3,867	***8,103***	*2,143*	50,2	41,5	42,1	**A**	**C**	**E**
VI	MM-1	384,0	38,92	2.437,30	1,402	1,920	1,346	***2,732***	*0,784*	31,6	26,6	26,5	**A**	**C**	**E**
	MM-2	346,0	38,92	2.437,30	1,114	1,128	0,983	***1,865***	*0,407*	20,6	41,5	21,4	**A**	**C**	**E**
	MM-3	263,0	38,92	2.437,30	1,786	3,728	1,901	***4,549***	*1,511*	30,0	11,2	16,5	**A**	**C**	**E**
	MM-4	278,0	38,92	2.437,30	5,977	6,367	4,066	**9,633**	*2,502*	53,7	37,9	44,2	**A**	**C**	**E**

5. CONCLUSION

The estimate of shock wave effects on constructed facilities and the environment, while carrying out blasting activities at the open pit Ranci, was made at surrounding constructed facilities according to the criteria of IPERAS, Russian standards for mine facilities and DIN-4150. On the basis of the carried out measurements it can be concluded:

- the recorded values of oscillation velocity in the vicinity of the mine (the measurement points: MM-1, MM-2; MM-3 and MM-4), meet requirements within threshold values, thus *do not affect constructed facilities.*

- predominant frequencies range from 25,5 – 35,5 Hz, thus do not affect people in the surrounding facilities.

- for more detailed perception of blasting effects on constructed facilities, it is necessary to establish the state of constructed facilities (the way of constructing, the resistance of facilities, the age of facilities, etc.), as well as to monitor occasionally shock waves in the vicinity of the mine.

- in addition to determining of blasting effects on constructed facilities, the KB_{fm} values, namely the impact of rock mass oscillation velocity on environment, were also determined. The KB_{fm} values according to the results presented in Table 10. with constructed facilities where measurements were conducted do not exceed threshold values according to.

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